Linux: Understanding Process-Level Power Consumption

Aurélien Bourdon, Adel Noureddine, Romain Rouvoy, Lionel Seinturier

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Green **C**omputing **M**iddleware'11

December 12th 2011

Inria ADAM

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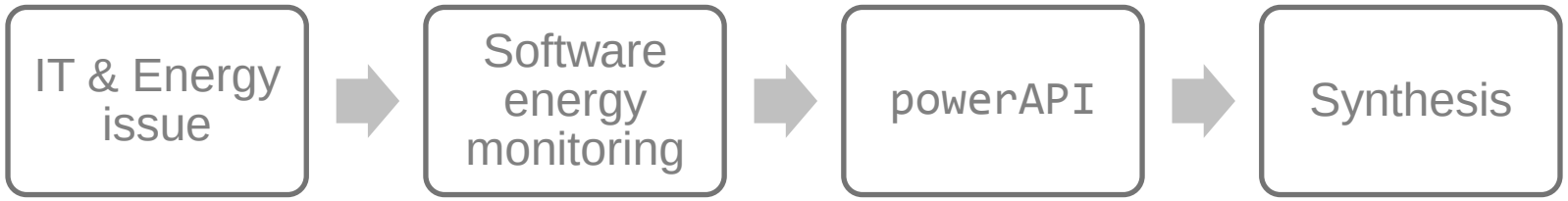
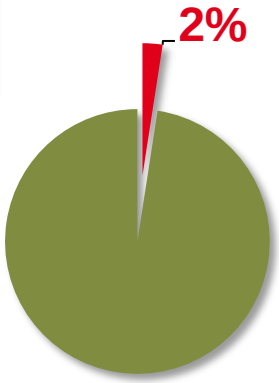
Outline


IT & Energy issue
Software energy monitoring
powerAPI
Synthesis

Information Technologies & Energy issue

IT & Energy



World wide carbon emission

=

Gartner group report

French electricity consumption

=

8x

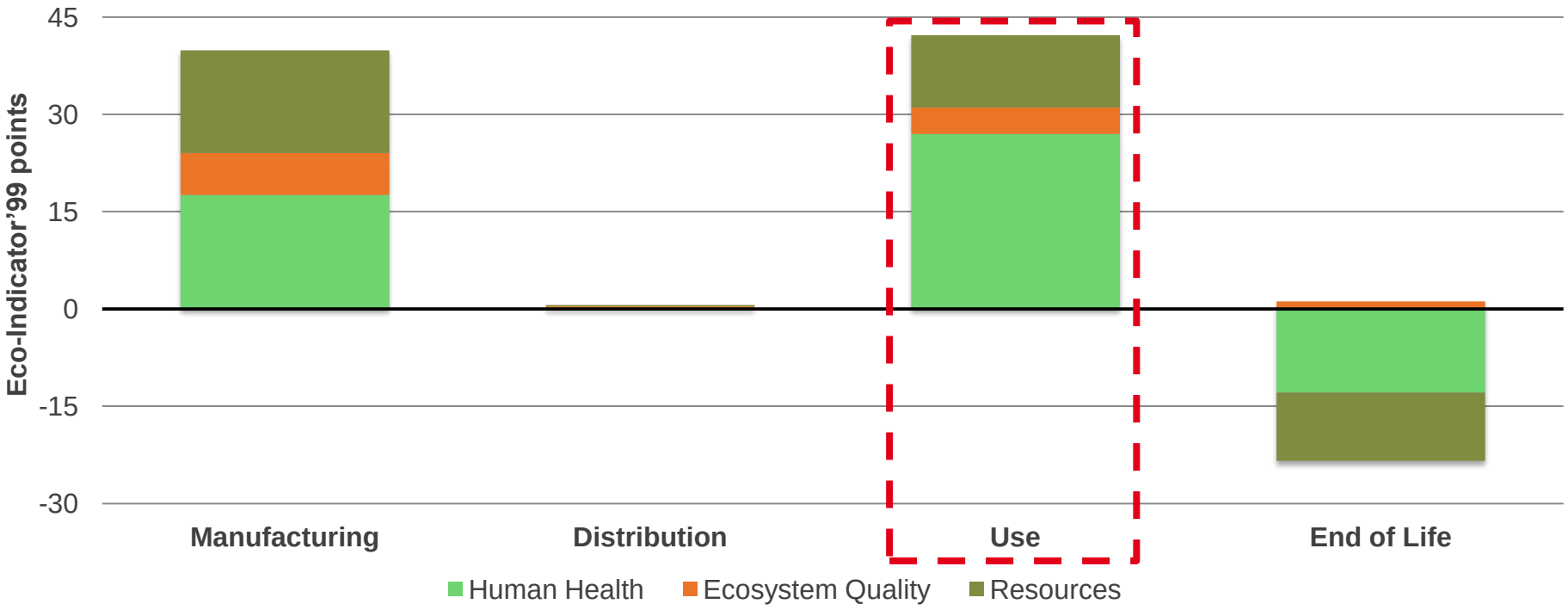
8x

French ministries. IT & Sustainable Development report

10% increase by year, over the past 10 years

IT: Where is the energy consumed?

Life Cycle Assessment (**LCA**) for a common PC



Duan & al. Life cycle assessment study of a Chinese desktop personal computer

IT & Energy: Towards a software concern

Hardware optimizations… but not software

Energy intelligence software is… out of software

Software is not energy aware by design

Software has to be energy aware

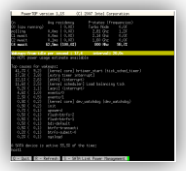
Tools which could help developers to visualize energy consumption

Discover new green development methodologies

Software energy monitoring

State-of-the-art

PowerTop



There are not reusable libraries

JouleMeter

Not easy to support platform interoperability

pTop

Development is over

Manual calibration

EnergyChecker

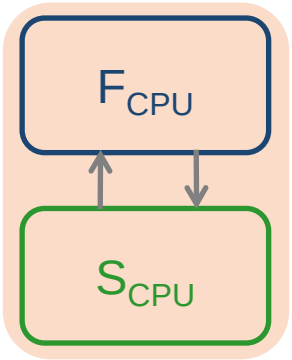
Requires external device

Our solution: powerAPI

Architecture overview

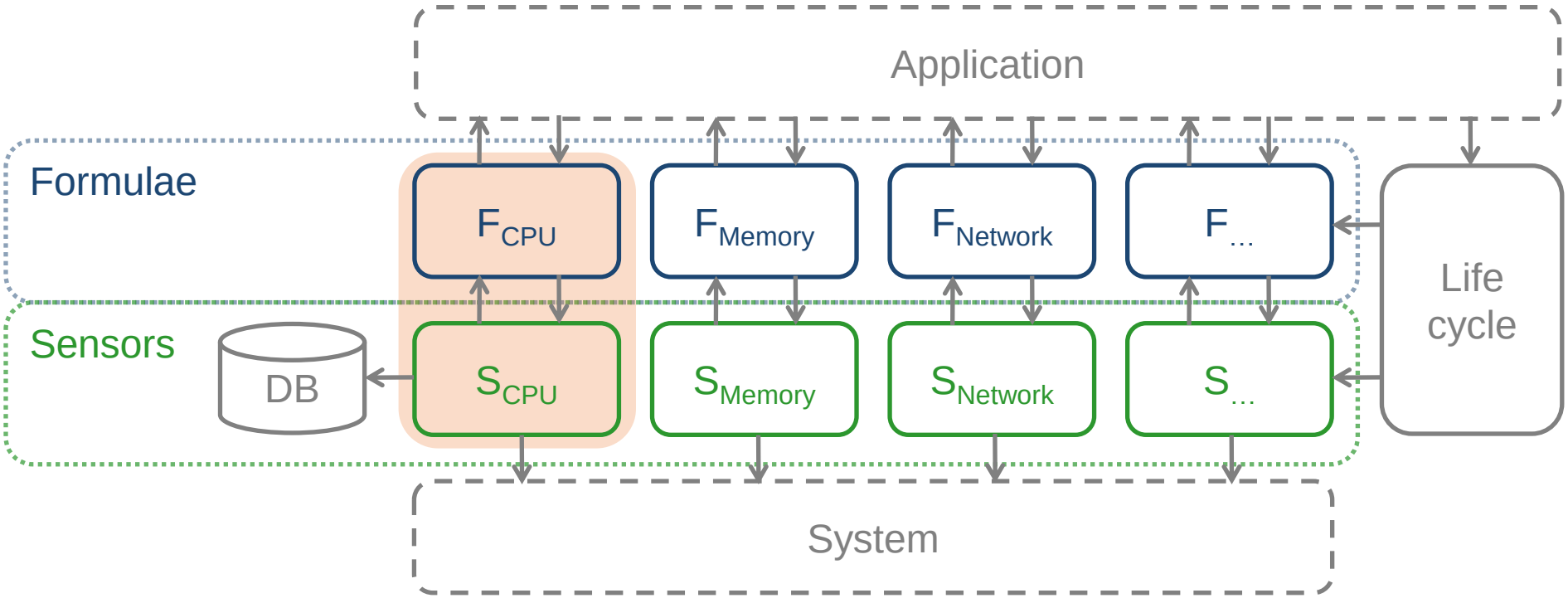
Energy module
=
Process(es) energy profiler through a specific hardware component

Energy module = **Formula** + **Sensor**



As many sensors as there are specific environments

Architecture overview



Architecture benefits

Modular approach, easy to extend

Interoperability

Adaptation to the execution platform, auto-calibration

Adaptation to the application needs

How does it work?
CPU case study, Linux system

How does it work? CPU case study

$$P_{CPU}^{PID}(d) = P_{CPU}(d) \times U_{CPU}^{PID}(d)$$

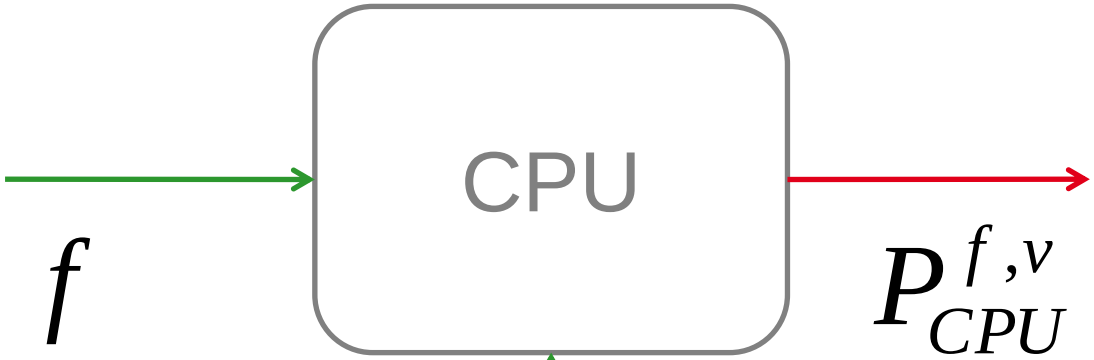
Process CPU power

Global CPU power

Process CPU usage

Global CPU Power		Process CPU Usage	
Static part	Dynamic part	Process CPU time	Global CPU time

How does it work? CPU case study



$$C \times \times v^2 = \quad [1]$$

Static part

Dynamic part

[1] Ge & al. Improvement of Power-Performance Efficiency for High-End Computing

Global CPU Power		Process CPU Usage	
Static part	Dynamic part	Process CPU time	Global CPU time

How does it work? CPU case study

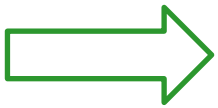
Static part is made up of several constants hard to find out…

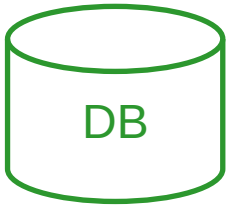
That's why we used constructor's **T**hermal **D**issipation **P**ower value

$$P_{CPU}^{f_{TDP},v_{TDP}} = TDP \times 0.7$$

Rivoire & al. JouleSort: A Balanced Energy-Efficiency Benchmark

$$C = \frac{P_{CPU}^{f_{TDP},v_{TDP}}}{f_{TDP} \times v_{TDP}^{\ 2}}$$





Global CPU Power

Static part | Dynamic part | Process CPU Usage: Process CPU time | Global CPU time

How does it work? CPU case study

We need to have

All frequencies used by CPU during the *d* period

Correspondance table between a frequency and its voltage

Global CPU Power 

Static part 

Dynamic part 

Process CPU Usage

Process CPU time

Global CPU time

How does it work? CPU case study

Frequencies used by CPU during d period

`cpu-freq-utils` tool

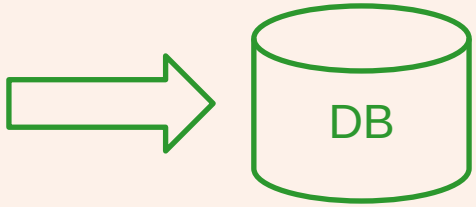
```
/sys/devices/system/cpu/
|_ cpu[0-n]/
 |_ cpufreq/time_in_state
```

2,8 GHz	70722 ms
1,599 GHz	4477 ms
…	…

Correspondance table between frequency and voltage

Constructor's data

2,8 GHz	1.5 V
1,599 GHz	0.8 V
…	…



Global CPU Power

Static part ✓

Dynamic part

Process CPU Usage

Process CPU time

Global CPU time

How does it work? CPU case study

$$P_{CPU}(d) \times U_{CPU}^{PID}(d)$$

Global CPU power

Process CPU usage

Global CPU Power ✓

Static part ✓ | Dynamic part ✓

Process CPU Usage

Process CPU time | Global CPU time

How does it work? CPU case study

$$U_{CPU}^{PID}(d) = t_{CPU}^{PID}(d) \;/\; t_{CPU}(d)$$

Process CPU usage

Process CPU time

Global CPU time

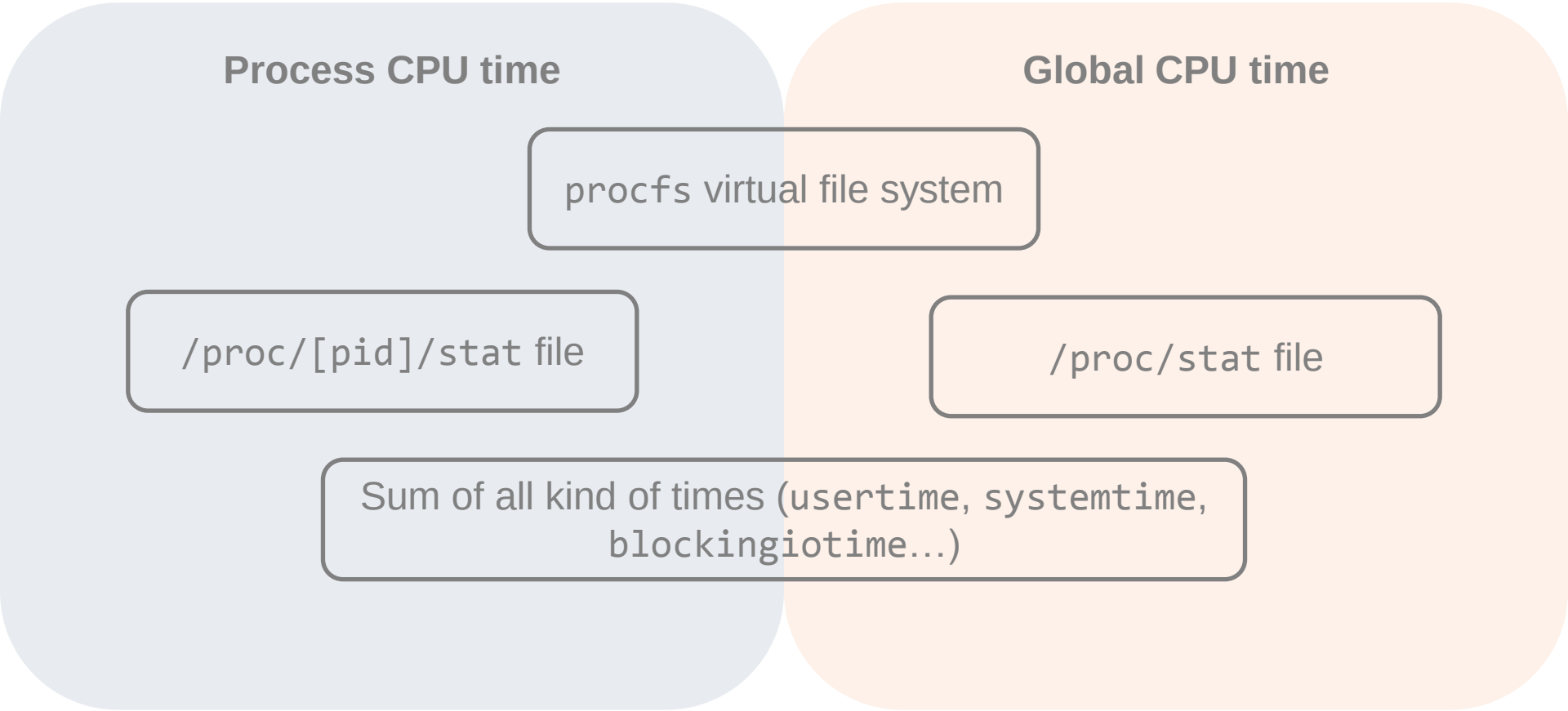
Global CPU Power ✓

Static part ✓ | Dynamic part ✓

Process CPU Usage ⚠

Process CPU time | Global CPU time

How does it work? CPU case study



Global CPU Power ✓

Static part ✓ | Dynamic part ✓

Process CPU Usage ⚠

Process CPU time ⚠ | Global CPU time ⚠

How does it work? CPU case study

$$P_{CPU}^{PID}(d) = P_{CPU}(d) \times U_{CPU}^{PID}(d)$$

Process CPU power

Global CPU power

Process CPU usage

Global CPU Power ✓

Static part ✓ | Dynamic part ✓

Process CPU Usage ✓

Process CPU time ✓ | Global CPU time ✓

Does it work?
Validation

Validation

Dell Precision T3400

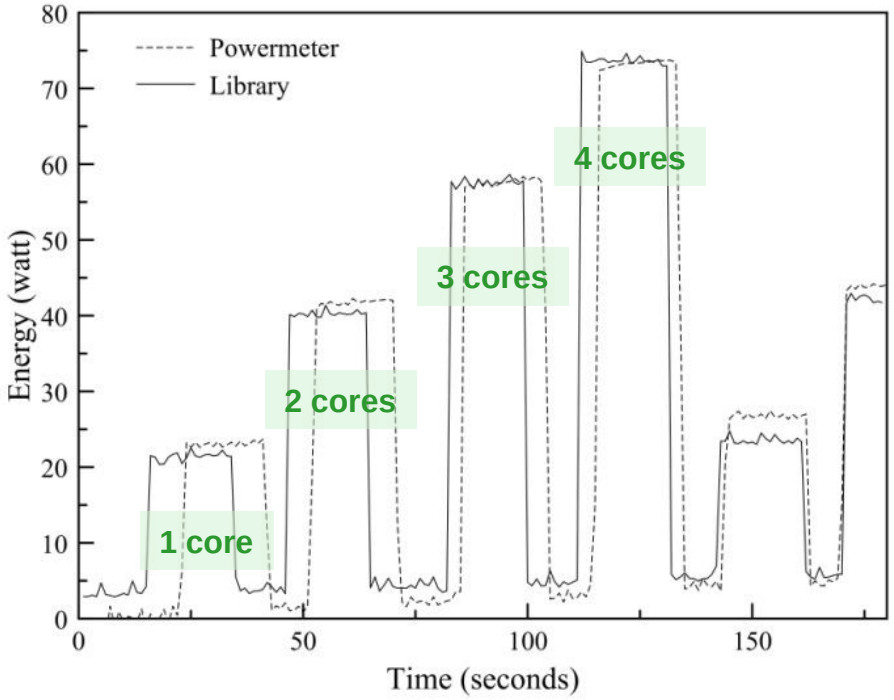
Ubuntu 11.10 generic
(kernel version 3.0.4)

Intel Core 2 Quad Q6600
(2.4 GHz)

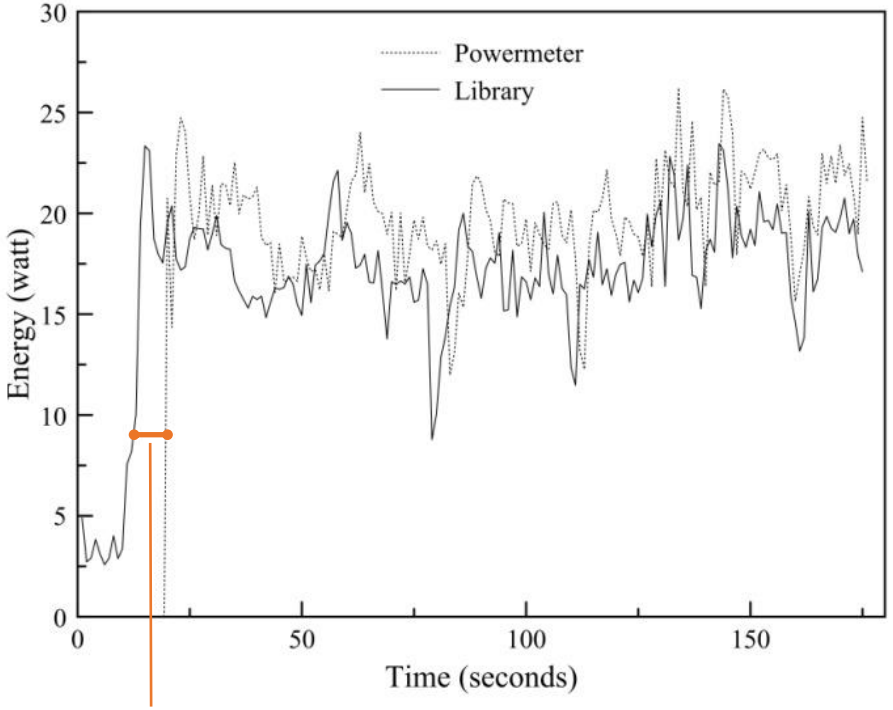
PowerSpy powermeter

Validation

`Stress` CPU stressor



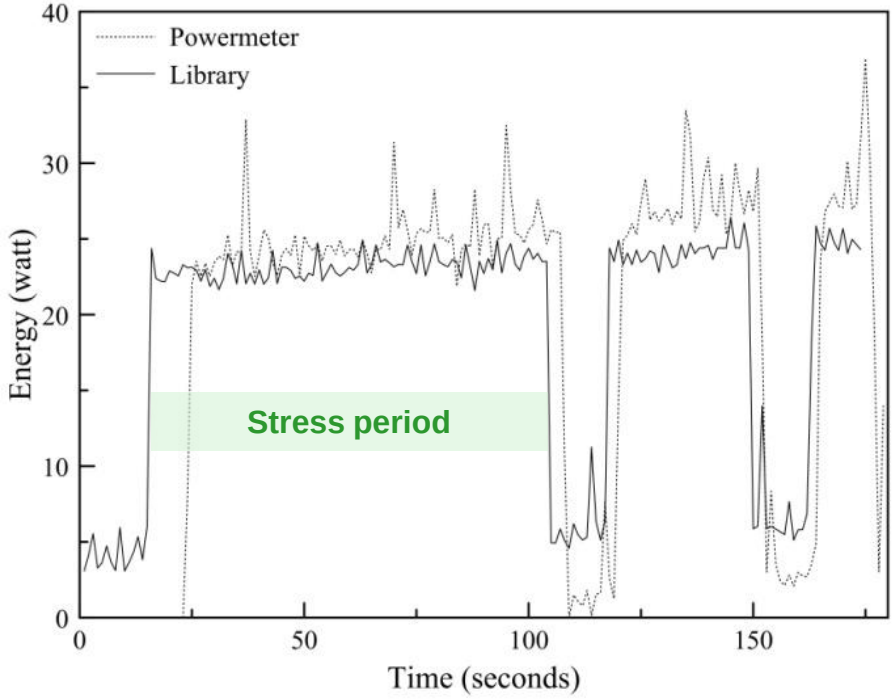
`Mplayer` movie player



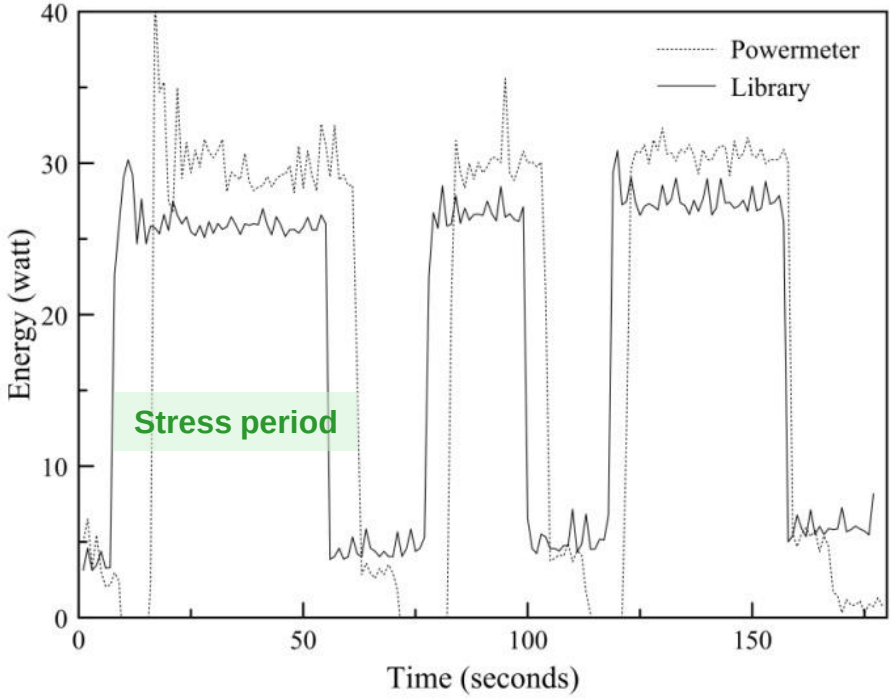
Time lag due to different refresh times between powermeter and `powerAPI`

Validation

Tomcat web server



Jetty web server



Conclusion & Perspectives

Synthesis

Need tools which could help developer to monitor software energy consumption

Some libraries already exist but integration and evolution are difficult

`powerAPI` = Process-level energy sensor library with a modular and adaptive architecture

We are working on new modules development (memory, disk…)

Applications

Some applications already exist

Process-level energy consumption visualizations

Monitoring and profiling Java applications at runtime (eSurgeon)

Thank you!

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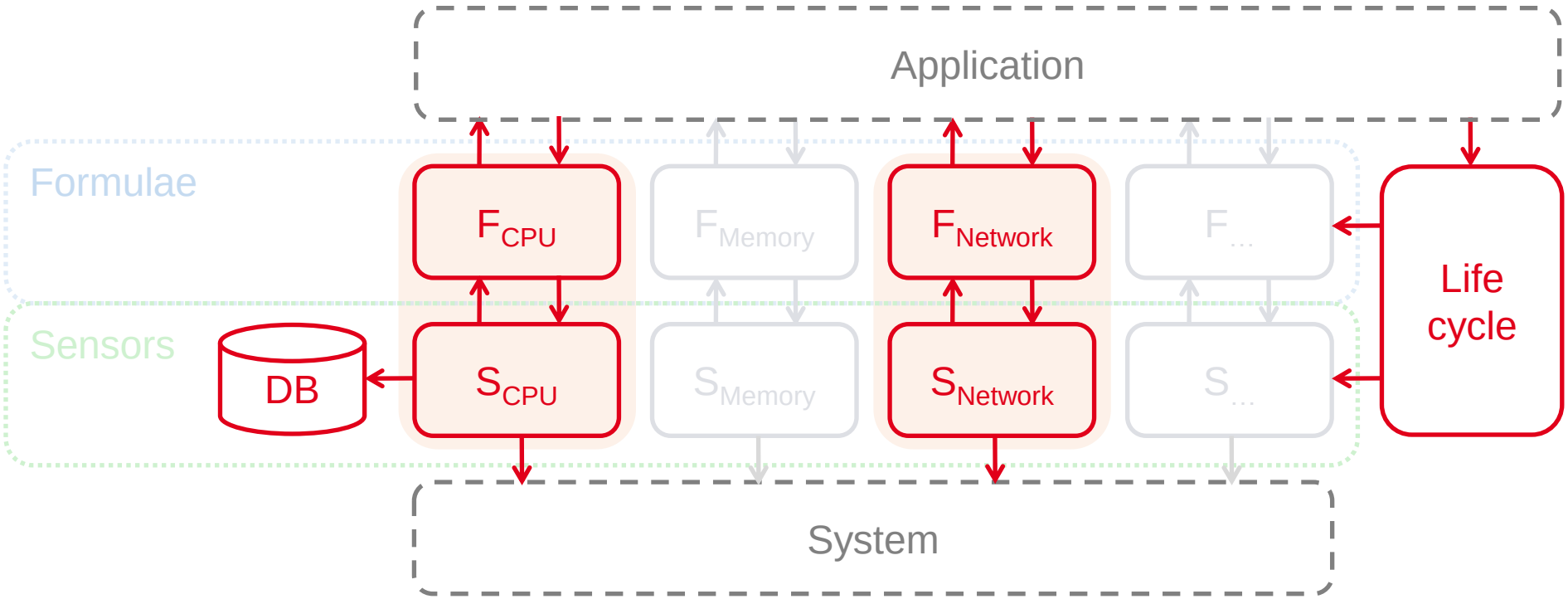
Backup slides

Architecture overview, current state



CPU power consumption formula

$$P_{CPU}^{f,v} = C \times f \times v^2$$

$$P_{CPU}^{f_{TDP},v_{TDP}} = TDP \times 0.7$$

$$TDP \times 0.7 = C \times f_{TDP} \times v_{TDP}^{\ 2}$$

$$C = \frac{TDP \times 0.7}{f_{TDP} \times v_{TDP}^{\ 2}}$$

Technical details

C++

Qt

SOF

CMake